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ABSTRACT

This monograph, first in a series of six, provides the theoretical background and premises underlying the efforts of the research team and two collaborating California school districts to explore ways in which the computer and related technologies can be more fully and effectively used in the instruction of learning disabled students. Contents include the following: (1) an analysis of key theories about mental functioning and remediation; (2) a definition of learning disability and consideration of commonly associated variables (genetics, maturation, drug effects, trauma, laterality and hemispheric dominance, sex differeces, orthography and handwriting, and sensory integration); (3) an examination of visual perception, functional vision, and reading efficiency; (4) cognitive processes (including memory, problem solving, and task strategies); and (5) promising computer applications (including use of the computer for vision training, perceptual enabling skills, and cognitive processing skills). (JW)

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Implications of Research and Theory for the Use of Computers With the Learning Disabled

Robert A. Weisgerber

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CREATE Monograph Series

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INTRODUCTION AND RATIONALE

This paper is intended to serve a particular function--the organization and exposition of the thinking that will underlie and guide the applied research of the staff at the American Institutes for Research, and cooperating colleagues in two collaborating school districts--Cupertino Union School District, Cupertino, California, and the Fremont Union High School District, Sunnyvale, California--as we explore ways in which the computer and related technologies can be more fully and effectively utilized to benefit learning disabled students. Beyond that primary purpose, the paper may be helpful to others who are addressing the special needs of these exceptional learners. For example, it will synthesize some of the thinking and research of others which bears directly or indirectly on meaningful communication between humans and between humans and machines, as well as factors that inhibit or enhance it.

At the outset, however, a caveat is necessary. Borrowing a phrase from J. R. Pierce, (1961, p. 108) an eminent physicist, mathematician and Director of Research, Communication Principles in the 50s for Bell Telephone Laboratories, we will lay claim only to "informed ignorance," not to knowledge at the level of scientific fact nor to laymen's uninformed guessing. Pierce eloquently argues that informed ignorance is "held in higher esteem than scientific fact" and is necessary for the scientist "to air what he is doing." It is in this constructive context that we make the following observations about the literature, draw implications for instructional design, and offer ideas and suggestions about potentially fruitful areas for applied research.

The observations and interpretations expressed herein will be applied in CREATE (Center for Research and Evaluation in the Application of Technology to Education), a planned four-year research study conducted by the American Institutes for Research under a grant from Special Education Programs, Department of Education. Three "sister" projects, also funded from SEP, will address different aspects of the computer use/handicapped learner interface. Hopefully, in the aggregate, these projects will add

substantially to our understanding of how we can enhance learning for these special people.

The point of view which we take can hardly be better stated than to quote Chalfant and Scheffelin (1969):

> A common approach to teaching children who have failed is to give them increased attention by placing them in a smaller group or working with them on an individual basis. In these cases, children often receive "more of the same" developmental approach under which they have already failed. The efficacy of the "more of the same" approach is questionable.
>
> Because many of the corrective approaches to reading were not successful in teaching reading to children who had failed, remedial procedures wre devised for ameliorating the psychological deficits thought to underlie poor reading. Remedial approaches are intended to remedy or ameliorate the underlying factor or factors which are contributing to the problem. While this approach may utilize the child's assets, the deficient areas are the target of instruction. If a child has poor auditory memory or visual discrimination, for example, a remedial approach might include procedures designed to improve these areas.

In an effort at facilitating the reading of this paper, we need to explain our premise that <u>performance</u> in school (e.g., spelling, reading, math and the achievement of specific subject-matter related objectives), cannot reasonably be expected to occur within an individual learner unless he or she is able to <u>process</u> information at the cognitive level (e.g., memorizing, reasoning, classifying, generalizing), in turn, processing cannot take place in the absence of <u>enabling</u> skills (e.g., discerning stimuli and cues through sensory channels, recognizing patterns and relationships in the perceptual field, and tracking, focusing or otherwise concentrating one's receptive powers in intentional ways), and this perceptual functioning is dependent on <u>visual</u> skills involving psychophysiological factors such as tracking and fixation, binocular coordination, and accommodation.

Logically and intuitively, we believe that many learning disabled students are dysfunctional in some subset of enabling skills, preventing them from processing information in line with demands on the learner

within specific academic performance domains. We acknowledge that not all dysfunctions lend themselves to solutions through computerized instructional strategies--brain injuries are not "repaired," for example--but we have enormous faith in the potential of humans (and the handicapped in particular) to cope. We plan to develop new approaches and techniques that are consistent with the findings of past research (some of the best being done a decade or more ago) and with experienced teachers' judgments about important needs with respect to enabling and processing skills in the CREATE study.

We will develop our discussion from the general to the specific, beginning with an analysis of key theories about mental functioning, moving to a definition of LD and a consideration of commonly associated variables, then to vision, visual perception and cognitive processes, and finally to computer applications that seem promising.

Mental Functioning and Remediation

Lerner (1981, p. 139) identifies nine categories of remediation as shown below:

Remediation of Learning Problems

Analysis of Child	Analysis of Content	Analysis of Environmental Conditions
Cognitive Processing Approach	Specialized Techniques Approach	Behavioral Approach
Sequential Stages of Developmental Approach	Skills Development Approach	Psychotherapeutic Approach
Test-Related Approach	Materials Approach	Pedagogical Approach

It is clear from Lerner's model that decisions about child need, the content to be presented, and the form of learning environment are separate

issues; for example, one can identify discrepancies through a test analysis of a child, then address them using a materials approach in a behaviorally oriented learning environment. The offering of incentives to reach criterion performance levels in math operations, using drill and practice materials, would be an example of one possible combination in the model. The model only serves to clarify alternatives, however, not guide one in making decisions about appropriate combinations.

To understand the trade-offs involved in making decisions of a diagnostic-prescriptive nature it is important to establish a conceptual framework within which the decisions are to be made. A review of selected literature can be helpful in that regard.

Theories of mental functioning

It is natural to first look to Guilford's Structure of the Intellect model (Guilford, 1971). In it, five operational components are named, six product components, and four content components. When displayed as a three dimensional model, 120 cells are created representing discrete intersects of operations, product, and content. We need not list them here, but merely point out that the model is essentially a static way of organizing functional relationships that contribute to human intelligence. Meeker (1969) applied the model to intelligence tests commonly used by educational diagnosticians. With several colleagues, Meeker then translated the structure of intellect cells into specific instructional tasks designed to develop the particular ability located in each cell. (Meeker, Sexton & Richardson, 1980)

A second model that has had considerable effect on educational philosophy is the concept of intellectual development as developed by Piaget. In summarizing Piaget's work, Lerner (1981, p. 162) points out the assumption that sensorimotor learning takes place in the first two years of life; learning characterized by direct action on the environment (e.g., hitting) and observations of effect. During years two to seven, preoperational learning takes place; learning is heavily perceptual in nature (e.g., seeing an animal), involves associative naming (cow,

rabbit), and awareness of object properties and relationships in the environment are emerging. During years seven to eleven concrete operations dominate; learning now involves organizing thoughts logically and envisioning relationships between acts in an if-then manner. Starting at about age eleven, thought processes move toward the formal operations level; learning becomes much more learner controlled and abstract thinking permits the conceptualizing of alternatives not yet encountered experientially, leading to problem-solving abilities. Central to the Piaget position are the ideas of maturation and readiness, which have been central in many educational (and particularly special education) curricula.

In that vein, Bruner (1961) has pointed out that fifth graders are capable of learning to use advanced mathematical concepts (i.e., the theory of functions) following concrete operational rules, even when they are not mature enough to grasp the formal mathematical theory itself. He argues that intellectual development is not a "clockwork sequence of events" but rather that it is incremental and influenced by environmental opportunities that challenge the student to forge ahead in his or her own development.

Bruner's analysis leads to four "themes" essential in learning. They include the ideas that:

1. comprehending a subject matter in a way that promotes generalization depends not on acquiring facts and techniques but rather on learning its fundamental structural nature,
2. the foundations of any subject can be introduced at any age in some form, but that readiness for learning dictates the form that must be used,
3. intuition and making shrewd guesses can be trained, so that original thinking (hypothesis testing) is encouraged, and
4. learning is dependent on interest and stimulation of the desire to learn.

Another theoretical approach was taken by Claude Shannon in 1948 when he developed his mathematical theory of communications, more commonly called information theory. This work was expanded by Wiener in 1965 in

his study of cybernetics of the nervous system, and by Broadbent (at about the same time) in applying information theory and decision theory to human perception and reaction. Information theory has helped by laying a groundwork for understanding why communication and learning can fail due to external "noise" (such as distractions) and suggests that there are capacity limits which, if exceeded, initiate a filtering and blocking mechanism that moderates learning.

Information theory, as advanced by Broadbent (1968), sheds light on how intellectual processes help to establish the probability of words occurring in a context; that there is an upward limit to the amount of information that can be actively "held" (for operational use) at a specific point in time; that "working rate" represents a functional lag between the time information is conveyed to an individual and the time it is reacted to; that properties in the field (such as patterns, contours, and edge lines) are the elements that the human sensory system must discriminate if information is to be abstracted. Similarly, Broadbent has related decision theory to human performance by pointing out the prerequisite need for detection (signal vs no signal), the probabilistic nature of choice-making between alternative detections, and the effect of the number of alternatives on reaction time. In simpler terms, this means that if learning is to take place one must notice the relevant informational item and that error rates will be influenced by the nature and number of alternatives presented.

This seemingly obvious idea has considerable implication for instructional design for the learning disabled. For example, those instructional approaches that start with simple, easily recognized stimulus materials and then slowly introduce complexities (e.g., abstractions and irrelevancies) fits will within information theory and decision theory. In incrementing the stimulus complexity, however, practice in each successive stage of difficulty must be assumed.

It is the general information processing model that will be adopted by the CREATE staff. In particular, we consider enabling skills to involve the learner's sensory perception of relevant stimulus properties

that lead to meaningful differentiation and identification; we consider processing skills to involve the cognitive organizing and restructuring of newly received information together with previously stored (remembered) information in meaningful, retrievable combinations, and performance skills to involve the expression of that aggregate of information through motoric responses in controlled, intentional ways.

Prerequisites in the learning process

Gagné and Briggs (1979) have organized cognitive learning theories as a set of six processes that occur in serial order. Each depends upon "structures" that must function effectively. They describe the processes as:

(1) reception of neural impulses--received from sensory receptors then delivered to the sensory register.

(2) selective perception--received from the sensory register, then delivered to the short-term memory.

(3) semantic encoding--received from short-term memory and delivered to long-term memory.

(4) retrieval--received from long-term memory and delivered to response generator.

(5) response organization--received from response generator and delivered to motor effectors.

(6) performance--leading to feedback and reinforcement.

Gibson (1968), a strong proponent of perceptual learning, argued against the notion that learning is dependent on memory. Although he did not deny that remembering can occur, he felt that

> "Recognition does not have to be the successful matching of a new percept with the trace of an old one. If it did, novelty would have to be the failure to match a new precept with any trace of an old one after an exhaustive search of the memory store, and this is absurd."

Learning by insight, according to Gibson, involves a kind of spontaneous perception of reality that is, how we operate on our environment (to produce effects) shows us what to expect. Learning to perceive involves looking for patterns of intensity, frequency, or separation--critical

features that can carry information. The process thus involves the detection of distinctive features and the abstraction of general properties. Since perceptual disorders are associated with a number of specific learning disabilities, we will examine the perception of critical features in somewhat greater detail later in this paper.

Taking an educationally-oriented view of learning, Haring (1974) and his colleagues at the Experimental Education Unit have identified six "phases of learning," including (1) acquisition, (2) demonstration and modeling, (3) mastery, (4) maintenance, (5) transfer, and (6) generalization. Interestingly, Haring states that on the basis of preliminary investigations at the Experimental Education Unit it appears that distinctly different types of learning occur in the development of each skill and that some instructional tactics are better than others during each of the developmental phases. Drill and practice, for example, are traditionally used in attaining mastery of a skill and can be used in its maintenance.

Learning Disability: Its Meaning and Factors Affecting It

At the outset, we need to acknowledge that a formal definition of LD has been adopted in federal legislation pursuant to the need for classification and placement criteria. Classification and placement are not the purposes of the project and the formal definition will not suffice, for it is less a functional definition than a set of assessment guidelines for inclusion or exclusion of a child within an administrative unit. (Given its length and wide use it need not be repeated here.)

Noting that the January 1983 issue of the Journal of Learning Disabilities featured a debate on definitions in which a number of experts clearly found it difficult to agree, we admit to seeing merit in several of the arguments advanced. The definition that most nearly matches our own thinking, for which there is a sound basis in the literature and suggests operational implications, is that of Cruickshank (1983). Accordingly, it is the one that we will apply in CREATE.

. . . "it can be stated that (1) learning disabilities are problems in the acquisition of developmental skills, academic achievement, social adjustment, and related emotional growth and development, which are the result of perceptual processing deficits."

A key to Cruickshank's view (and ours) is that learning is neurologically based. It is therefore important to consider the etiology and the dysfunctions that affect perceptual processes, particularly those involved in reading and language acquisition.

Genetics

European thought (Geneva Medico-Educational Service, 1968) in the late 60s, characterized dyslexia as an "anatomophysiological mechanism which causes disorganization or prevents the development of the lexical function." Four types were described:

1. Dyslexia is the result of a peripheric or central physical damage to the nervous system.
2. Dyslexia is the result of a specific type of disorganization which would follow a disorder of the hemispheric dominance.
3. Dyslexia is a constitutional and hereditary disorder.
4. Learning problems in reading are due to immaturity.

Grossman (1981) has reported on the recent work of Hier and a group of researchers at Massachusetts General Hospital who have been investigating a genetic basis for learning disabilities. They had mixed but suggestive results. On the one hand, no evidence of chromosomal abnormality was found for 20 adult men enrolled in remedial reading instruction, even though all had marked dyslexia since childhood. In contrast, among some 89 persons identified as having sex chromosome aberrations (according to records), they found a high incidence of mental retardation (20 cases) plus frequent learning, speech, and attention disorders. A clear link to hyperactivity was established as well.

For some years, Badian (1984) has studied the epidemiology of reading disability in the elementary grades. Her work, which took into account

chronological-age-in-class, used WISC-R data and years in school to compute reading expectancy. She then examined environmental conditions at birth for middle and lower middle income families in the Boston area, and found a pronounced correlation with reading disability. Four percent of the 550 students sampled were categorized as having a reading disability (with WISC-R greater or equal to 85 and reading falling lower than the 20th percentile on the SAT total reading score). Of these, the ratio was 2.5 male to 1 female; the boys were significantly more likely to be born later in position in the family, and most important, the prevalence rate was extremely high for boys born in a month where the temperature was 71° or greater--7.1 times the rate for boys born in cool and moderate temperature months. Girls born in those months seem somehow less affected.

Maturation

These genetic perspectives are rather different than Shedd's (1968) view that "Operationally, dyslexia, or whatever one chooses to call it, may be defined as the failure to develop specific perceptual-motor skills to expected proficiency independent of instruction, motivation, sense organ functioning, intelligence, and CNS involvement,"--that is, it is a case of "arrestation of anticipated development." Shedd cites Gates' view (in 1922) that (1) perception involved discrete abilities (e.g., perceiving words, digits, geometric figures), (2) there was little evidence to show that poor and good readers differed with respect to visual discrimination of nonlinguistic material, and (3) it was due to poor educational methods, unfavorable home influences, emotional factors, and visual defects.

Maturation and growth imply change in readiness and capacity. In practice, learning disabilities are frequently described in discrepancy terms that attempt to contrast where the child is with where he or she is expected to be along a specific continuum of learning, especially in the performance skills of reading, math, etc. This view of maturation and learning disability necessarily leads to a remedial intervention model. However, it is equally important to study levels of maturation on a developmental basis, for it is this development rate that may be influenced by appropriate preventive instructional interventions.

An important point needs to be made here about developmental lag. Since cognitive and mental development in the first five years of life is rapid (Lichtenberg & Norton, 1972) it is hard to set benchmarks that can reliably predict evolving deficit conditions. On the other hand, if one waits until the deficits are clearly identifiable (in the elementary school), then remediation is needed and the negative effects of the deficits are already working against the child.

To the extent possible, it would be better to involve pre-schoolers in appropriate activities, such as computer "games", designed specifically to encourage them to practice basic enabling skills as soon as they can--that is, within the limits of neurophysiological factors involved in the maturation process.

Ames (cited in Lerner 1981, p. 160) goes so far as to state that learning "disabilities" result when educators "overplace" children in relation to their maturity, thereby aggravating learning problems that may already exist and causing problems where good potential exists. It is important, then, to distinguish between trying to teach reading per se too soon and providing the child with foundation skills for reading readiness at an appropriate age. The question remains, when is it appropriate to introduce children to tasks that are relevant to reading?

Hurst (1968) credits Frostig with recognizing four main stages of developmental growth:

1. Sensory/motor--birth to age two
2. Maximum speech development--up to age four
3. Maximum perceptual development--age 3-1/2 to 7-1/2
4. Higher cognitive processes (if stages 1-3 were accomplished) develop after age 7-8.

Moreover, maturation rates tend to be different for boys and girls, so that if one were examining motor coordination involving handwriting, for example, sex differences should be considered just as should "handedness."

Estes (1976) has summarized age trends in attention and short-term memory that have implications for CREATE's design of interventions. Some of the more relevant conclusions are that

a. attention (the focusing on an experimental task and excluding distraction) is so strongly age related that it is "very difficult to do accurate work on selective attention with young children."

b. in short-term memory "structural and functional properties of primary memory seem to be strikingly independent of age, from early childhood to adulthood, from mentally retarded to college educated subjects,". . ."the slopes of short-term retention curves prove almost invariant with respect to age and intellectual ability,". . . and "the process of encoding of information in short-term memory seems not to change qualitatively over a wide age range."

c. changes in mnemonic abilities are conspicuous with increasing age but "appear to be associated with rehearsal, organizational, and retrieval strategies."

Finally, there is the general issue of whether one "grows out" of LD or whether one simply learns to cope and/or mask deficiencies as a function of increased age. Certainly Dale Brown (1982), herself learning disabled but an active advocate for self-help among adult learning disabled persons, maintains that you never outgrow it. Speculatively, we suggest that unless the deficit condition is somehow remediated the adult will continue to fail in perception-based enabling skills that support a wide variety of tasks (operating a cash register, reading stock numbers, taking oral directions), thereby limiting their employability.

Drug effects

A number of learning disabled persons, especially those exhibiting hyperactivity, aggressive or volatile behavior, are in programs where drug therapy is prescribed. The effects of these drugs on learning must be taken into consideration, but it is not an easy or simplistic process. Although attention can be prolonged by drugs (in some cases), and changes in mood, personality, concentration, perception, and motor coordination can be expected when drugs are used, the effects are not always positive and are apt to be complex.

It will be necessary to adjust experimental designs in CREATE to take this special subpopulation into account. That is, we will need to be cautious in interpreting what skills are learned independent of drug effects.

Trauma

Minimal brain damage is a term commonly associated with specific learning disabilities. To the extent that the damage is congenital (birth-related) and not adventitious (caused by childhood disease or localized injury) it is typically inferred through "soft signs," such as motor awkwardness or poor speech production.

When organic damage occurs through injury such as a gunshot wound there are often sharply varying aspects of behavior prior to and following the injury. For example, speech production can be affected in very specific ways. The part of the brain in which the injury occurs (frontal, temporal, parietal, or occipital lobe), has a bearing on the kind of dysfunction that results as well as the prospect for "retraining" up to previous proficiency levels. Effects can be:

1. pervasive (speech production with left frontal lobe)
2. selective (concept learning with right temporal and parietal areas) (Federico, 1983)
3. functional (damage to the temporal cortex can interfere with the act of remembering and interpreting things that are seen and heard while damage to the frontal lobes can cause the person to be less attentive, less vigilant, and perhaps more distractible) (Chalfant & Scheffelin, 1969).

Difficulties in "perceptual classification" have been shown to be associated with lesions in the right hemisphere and the same is true for spatial discrimination ability (e.g., differentiating between pairs of symbols) (Carey-Block, 1974).

The effects of surgery can also affect the response patterns of individuals. For example, the film Left Brain, Right Brain (Filmmakers Library, Inc., NYC) depicts a young adult whose hemispheres were

surgically separated in order to stop the migration of epileptic seizures from one hemisphere to the other. In subsequent presentation of simple drawings (dog, tree) tachistoscopically and separately to each eye, it was observed that he responded either vocally to name the stimulus or by spelling with anagram-type letters depending on the hemisphere that had received the perceptual input.

Clearly, then, it is impractical to expect that all learning disabled persons would respond beneficially to a particular instructional program no matter how carefully instructional materials are designed or by what medium they are presented. This implies the need for careful differentiation of learners involved in CREATE studies so that our investment in training design and teachers' efforts are wisely spent and experimental results are not artificially restricted.

Laterality and hemispheric dominance

For over four decades, since Orton's 1937 study of reading, writing, and speech problems in children, there has been attention to the relationship between specific difficulties (e.g., letter and word reversals by dyslexics) and poor lateralization or cerebral dominance (Geneva Medico-Educational Service, 1968). For the large majority of the population, it is generally conceded that the language function is left hemisphere dependent, while the right hemisphere controls the nonverbal function, including visual spatial perception, directional orientation, and temporal sequencing (Lerner, 1981).

"Motor skills involving strength, repetitive speed, and tool use tend to be performed better by the right side, whereas motor skills involving spatially accurate placements, tactual or visual and regardless of speed, tend to be performed equally well or better by the left side of right preferring subjects" (Rudel, 1974). Furthermore, motor skills develop first on the right side and then (by age 7) there is a rapid increase in the left side. The difference remains more pronounced in learning disabled children.

Recent research at the Navy Personnel Research and Development Center has used event-related potentials (ERPs) to study the way in which the hemispheres and regions of each hemisphere contribute to concept learning. Concept learning using auditory stimulus materials, for example, involves the right frontal, temporal, parietal, and occipital regions and the left parietal area (Federico, 1983). Other research by the Navy (Lewis et al, 1981) studied brain amplitudes with respect to verbal tasks and spatial tasks. They found that "Typically, for people performing verbal tasks, there is decreased EEG and ERP amplitude over the left hemisphere. For spatial tasks, there is generally a decrease over the right hemisphere. Such decreases in amplitude are considered indexes of increased information processing within the affected hemisphere."

Higher order functioning, such as cognitive styles (e.g., field dependent vs. field independent) also have been shown, through quantitative EEG measures, to be related to lateral dominance. Field dependent types of individuals showed more similarity in electrical activity between the two hemispheres than the field independent types, who showed definite hemispheric dominance (Oltman, Semple & Goldstein, 1978). Thus it would appear that a clue to cognitive style rests in the difference between the level of brain activity in the two hemispheres on behavioral tasks.

These and other studies on lateralization by researchers Bagnara, Simion, Roncato, and Umlita of the Instituto di Psicolgia del CNR (Grossman, 1981) suggest that CREATE studies may benefit from including data on learners' lateralized preferences. Such information might include foot and hand preference, tests of speed and skill with the hands and feet (such as finger tapping), tests with the eye and the visual field (speed of reaction to stimuli in the right and left fields), and tests with the ear (in responding differentially to sounds).

Sex differences

There is evidence (apart from maturational and biological differences) to indicate that there are sex differences in the way in which

the hemispheres function cognitively. When young adult males and females, all right-handed, were given a comparison task using visual images (geometric figures) presented differentially to the right and left visual field, it was found that male subjects responded faster in the left visual field while females were faster in the right visual field. (Grossman, 1981)

In relating sex differences and dyslexia, there is a preponderance of evidence (Chall, 1983) that at the beginning reading stage boys and girls respond very differently to instruction, with girls attending more to detail and boys to holistic configurations--where integrated patterns are preferred. Witelson (1977) has conducted research that not only indicates there is a right brain spatial processing advantage for boys, but goes farther by suggesting that in dyslexic boys spatial processing can occur in both hemispheres, thus interfering with the specialized left hemisphere linguistic function. In turn, this implies that boys, more often behind in developing reading skills, should be taught via whole word techniques while girls might best be taught by phonic approaches.

Haddad, Isaacs, Onghena and Mazor (1984) have reported on the successful use of orthoptic training with some 73 cases (64 boys and only 9 girls) referred because of "reading difficulty" for opthalmological evaluation. They found 18 whose reading difficulty was attributable to refractive error alone, 18 with a perceptual defect but no orthoptic defect (which Haddad calls the dyslexic), and 37 for whom fusion of the visual image was not within a normal range. Following treatment, attention span improved as did length of time span in uninterrupted reading and recall of what was read. It would appear then, that for boys especially, special attention should be given to whether fusion is taking place properly.

The importance of fusion (the ability of the brain to resolve discrepancies between images received by the two eyes) in reading is obvious since binocularity is constantly present in readers with normal vision. As Haddad puts it:

> ...if fusion is relatively well established, but the fusional amplitudes are disturbed, especially at near, then a 'struggle' will ensue when the child attempts to maintain fusion, especially during the reading process. The difficulty will be much further aggravated when the child has an added perceptual problem as in dyslexia.

When convergence (the inward turning of the eyes to fixate a near object) and accommodation (muscular adjustments affecting the lens) are faulty to some extent the child attempts to fuse "at all costs," leading to fatigue and focusing difficulty. Word-by-word reading ensues. If there is convergency insufficiency diplopia results and the child may begin to "see" the words shifting backwards, right to left, while his eyes try to follow in this reverse direction. Many so-called bad reading habits, such as losing one's place during line changes, can result from these physiologic and perceptual malfunctions.

Also interesting is Hurst's (1968), four years of study in Canada relating reading proficiency and phoria for boys and girls in the primary grades. Phoria can be operationally described as a measure of how hard the person has to "work" to fixate both eyes on a target, or, conversely, the extent to which one eye tends to want to "drift off target" when that eyelid is closed. Sex differences were noted and interestingly so. At the first grade level, the measured near-point reading distance averaged 5.7 inches (which we will refer to as 6 inches); this is contrasted to 16 inches which is considered the "normal" near-point reading distance for the general population. When boys' and girls' reading performance was correlated with level of phoria or eye balance at the 6" and 16" distances, the data showed significantly <u>positive</u> relationships with reading performance at the 6" distance for boys in first grade and girls in the third grade. The third grade girls, on the other hand, showed a significantly <u>negative</u> correlation between phoria and proficiency in reading at the 16" distance.

Interpretation of these data are difficult, but it does suggest that CREATE should be alert to (1) screen-to-eye distances naturally selected by boys and girls, (2) any indicators of high phoria in the LD learners that might lead to fatigue in eye fixation and binocular control during

reading tasks, and (3) the effect of this capacity-limiting characteristic on learners' skill-building at the enabling level, where rapid recognition of the distinguishing features of letters and words will be stressed.

Orthography and handwriting

Sheridan (1983) has analyzed the differing prevalence of reading abilities in countries having markedly different orthographies. Noting that the incidence of learning disabilities is quite low in Japan (less than 1%) and that difficulties with Kana and Kanji scripts beyond fourth grade are rare, and that 95% of the two year olds own a book, Sheridan points out that Japanese letters are relatively simple in shape--between one and six strokes for each symbol. This is in marked contrast to Chinese, where there are 20 distinct brush strokes, and some 6000 different characters.

In the Latin based alphabet used in English, a letter or a combination of letters can represent one or several different phonemes, which combine in various ways with other phonemes. Given the nature of reading instruction in the United States, and the difficulty some children have in learning to read, and to distinguish between such concepts as word, phoneme, grapheme, and sentence, Sheridan states that "the emphasis on phonics as a method of beginning reading instruction requires a metalinguistic ability to reflect on the isolated sounds of the language apparently beyond the developmental or conceptual capacities of some young learners." (p. 83)

One possible implication for CREATE is that we might focus the LD learner's attention on letters and words as idiographs or "pictures." For example, the lower-case u is cup-like and can hold liquid, while an n cannot hold liquid.

The process of reading, of course, is not solely restricted to printed matter, which varies considerably in typestyle and size, but includes handwriting. Here, variation occurs within and across individual writers. It is essential that the reader of handwriting be able to

generalize a great deal in character and word recognition, depending much less on exactness of letter formulation and much more on context and "marker" letters (especially those with ascenders and descenders) and letter combinations (such as repeating letters).

The production of handwriting by the learning disabled represents a special skill requirement different from and added to the skills necessary for reading of materials set in type. It is probably not a coincidence that the learning disabled take quickly to the computer as a writing medium for it generates "print" similar to that which they are most exposed to in the course of their schooling. Observers of "computer friendliness" have commented on the ease of correction and modification in word processing programs as a reason for its attraction to the learning disabled. At a more theoretical level, however, it seems likely that there is cognitive efficiency (less demand on processing capacity) when the individual does not have to think at a meta-level, continuously perceiving printed text and/or typewritten test questions in their unique orthographic form and then having to transpose his or her responses into a cursive form.

In that regard, we should keep in mind that the act of production of handwriting is not only dependent on the conceptual knowledge of acceptable letter forms and the motor coordination necessary to generate those forms, but is also a function of a feedback loop in which the writer continually monitors (perceptually--both visually and kinesthetically) the production process and makes rapid adjustments as necessary (Smith & Smith, 1966). Again, the continuous cognitive switching that is called for at the perceptual input side is less demanding in computer interactions where the typeface on the screen is the same for both presentation and response.

Sensory integration

Sensory reception of stimulus materials, as has just been pointed out, can be complicated when the characteristics of the stimuli differ in terms of the "rules" that govern their interpretation. Reception is also

complicated when it comes through different modalities, as in the case of visual and kinesthetic feedback in handwriting. What is required is some kind of accommodation by the perceiver. This accommodation can be in the form of integration of the different sensory inputs or, when they are in conflict (regardless of whether the individual is aware of the conflict), a prioritization of one sensory input over the other.

For instance, experimentation some 20 years ago, in which feedback received tactually and visually was deliberately made to disagree, showed the dominant power of the visual mode (Rock & Victor, 1968). Other research, (Schmidt & Kristofferson, 1968) addressing attention span when visual and auditory input was simultaneous, indicated that the auditory channel was the first to be conducted to the brain.

There is also competition for attention when the teacher reads aloud and the learners are supposed to follow along visually. Some learners prefer to listen and quickly lose their place, some cease listening and read at their own pace, and others simply get confused because, as Lerner (1981), citing Goodman (p. 317) points out, the unit of language--the word--has greater importance in print than in speech. Thus a child <u>hears</u> an uninterrupted flow of sounds as the teacher reads, but <u>sees</u> a chain of interrupted symbols on the page.

Moreover, when a person reads aloud they do not always know how a word should be pronounced (e.g., tears) until the appropriate <u>meaning</u> is made clear from the remaining words in the sentence. Proficient oral readers make these contextual leaps as they go. Similarly, the same sounding word can appear very different in print (e.g., oral, aural), so that the proper pronunciation does not necessarily imply which word is being used--only print does that. Oral reading, then, is not necessarily a clarifying act to supplement the silent reading process. Lerner, (1981) taking note of the fact that LD learners have a lower tolerance for integrating information input systems at the same time, points out the risk of "overloading the perceptual system," which can lead to negative--even "catastrophic"--responses.

In spite of this dilemma, the "neurological impress method" is a relatively recent approach for teaching reading orally that tries to emphasize the oral impression (coupled with finger-pointing to the words that are being read) by having both the instructor and the learner read aloud in unison. The premise is that the oral feedback from the learner will reinforce the aural perception of the instructor's voice.

Insofar as the use of microcomputer technology is concerned, there are relatively few instructional programs in which audio and visual stimuli that mean the same thing are being presented concurrently to learners. No doubt this is due largely to the emerging nature of speech generation output devices, but as they become available and are more widely used in the schools (and in possible experimentation in CREATE) care should be exercised that the multi-sensory demands for the learner's attention are neither wastefully redundant nor competitive for limited processing capacity but rather are designed for reinforcement. For example, it would be reinforcing to have speech-generated words on the monitor activated by the learner's voice. This might lead to breakthroughs for many LD readers and is probably an area that should be explored in the future as speech generated input to the computer becomes affordable.

Computerized Displays and Visual Perception

Because stimulus generation for information transfer by computer is primarily visual in nature, with audible output from the computer being typically used for pacing (e.g., ticking sounds), for interest (e.g., sound effects), for reinforcement (e.g., musical rewards), and other supportive purposes, we need to look very closely at the potential of the medium for manipulating the visual display to "teach" visually-oriented perceptual skills.

The research literature in visual perception is rich: the opportunities for translation of this research into program strategies are numerous and potentially valuable. For instance, if the computer can help to

distinguish "whole perceivers" from "part perceivers," (i.e., those who grasp the whole Gestalt versus those who notice a part at a time), and help to show children how to use each kind of perceptual skill depending on the task, it would be a welcome advance.

We will examine the broad topic of visual perception through a set of topically-related questions.

Visual Perception, Functional Vision, and Reading Efficiency

Studies of involuntary eye movement have shown that the eye is virtually always in motion--either through a slow drift of the eye, a tremor imposed on the drift, or through saccades, the jerky movement that occurs as the eye scans the visual field for purposes of information acquisition. Heckenmueller (1968) pointed out that "The effect of the movements is primarily one of overcoming the loss of vision resulting from constant stimulation of the retina. Stated another way, the effect of the movement is to provide changing sensory stimulation of a spatial variety."

Anatomically, the retina receives images through the rods and cones. Motion is perceived through the peripheral rods; the cones of the fovea centralis then pick up details and perceive color when the eyes turn to focus on the moving object. The foveal cones are critical both to distinguishing far objects and to discerning the details of print (Vaughan, Asbury & Cook, 1971). The path from the retina to the cortex consists of at least six different types of nerve cells, all of which are organized into receptive fields and serve either to excite or inhibit stimulation by light. It is thought that these different types of cells are specialized to evaluate only a limited number of dimensions of the visual stimulus: (1) frequency, (2) intensity, (3) pattern, (4) orientation, (5) position, and (6) movement of the visual stimulus (Heckenmueller, 1968).

Some time ago, Bruner (1960) pointed out the importance of "gating" as mechanism by which particular retinal cells receive stimulation but

receptivity in the immediately adjacent ones is suppressed. This is an essential phenomenon in that it allows edge lines and definition to be perceived. In this regard, there is evidence that the pattern of firing on the retina is affected by pupillary changes and that during conditions of binocular rivalry there is less sensitive pupillary reflex in the non-dominant eye. In effect, this means that different sensory inputs received by the two eyes may produce inconsistent "messages" to be retained in short-term memory.

A critical aspect of eye physiology is the ability (or lack of it) to see binocularly. In order for binocular vision to be advantageous, however, the eyes should be able to present to the cerebral cortex reasonably consistent images. As mentioned previously, several factors are involved, including the ability of each eye to resolve and focus on an object through muscular control of the shape of the lens, the ability of the eyes to converge on a target, and the ability of the visual-neural system to fuse the disparate images which necessarily result from the different perspectives of each eye.

Fortunately, new techniques have been developed, and are in active use at leading centers of optometry and ophthalmology to help individuals develop better binocular vision. For example, there are several ways to reduce excessive phoria, the drifting of one eye markedly in some direction away from the target, causing fatigue and poor fusion of the target in binocular vision. Computer-based vision training in this area is now commercially available; CREATE will investigate it further.

The eye sustains an image long enough so that a series of still pictures shown as slow as 15 frames per second will be "seen" as "a motion picture." It is also true that very brief exposures to light stimulation can wipe out perceived stimulations received only 50 msec. earlier. This has consequences with regard to the temporary-memory storage of visual input, since this memory can be obliterated by a subsequent signal (Boynton, 1968). This is the case when we scan text rapidly.

As for the relationship between reading performance and saccades, fixation and foveal and peripheral viewing, it has been shown by many investigators that, by the 5th or 6th grade, good and poor readers differ in these factors.

GOOD READERS	POOR READERS
- lengthened horizontal span per saccade (longer jumps between fixation points)	- saccades are short in span and numerous
- shorter duration of fixation, with efficient use of the "resting" period when information is taken in	- overly long fixations at each point
- less frequent regression to previously fixated words	- frequent regressions to previous words
- use the visual periphery as cues to minimize the demand for item-by-item decoding	- foveal viewing emphasis, with little use of the periphery

Fisher (1980) has summarized the research on these factors as they apply to disabled readers. Some interpretations of this research are:

1. The average duration of fixation is 250 msec, of which the first 50 msec is needed for decoding and the balance is available for peripheral previewing of subsequent text. Reading disabled persons fixate longer than normal readers, even quite young ones. This extra storage time is believed to be disruptive and leads to memory overload and confusion about the relationship of elements in the text.

2. When text is "mutilated" by elimination of the spaces between words or by alternating upper and lower case within words, good readers are forced back to a reliance on concentrated foveal decoding, with little use of the periphery. As a result they read word-by-word (at rates less than 40 WPM) and their eye movement dynamics are similar to those of the reading disabled. Fisher (p. 27) points out that this finding is consistent with models advanced by Hochberg and by Laberge and Samuels. Hochberg's emphasis was on the importance of peripheral and search guidance mechanisms in which the periphery is used to alert the reader to such cues as word shape and spacing to "advance organize" foveal intake of the word image. Laberge and Samuels emphasized the importance of experience (practice) in building automaticity so that the foveal intake is quick and processing requires minimal effort.

3. Given orally presented lists of seven words, reading disabled children could repeat them at an equivalent level (children matched by reading level and age level). When a reading-level list was presented visually to the reading disabled they managed to recall two of the seven words, but when the list was at age-level they recalled only .1 of the seven. Presumably, there is greater facility for storing aimpler words in memory, suggesting the possiblity that automaticity is taking place at the perceptual level, leaving more opportunity for cognitive classification and "refreshing" the memory traces prior to recall.

4. When sentences are presented in anagram form, the reading disabled perform as well as normal readers, and at a rate equal to their usual reading of regular sentences. This is consistent with the idea that there is a relative advantage for the reading disabled in foveal processing, or, conversely, that anagrams eliminate the advantage normal readers usually have in using the visual periphery.

McConkie (1982) applied computer technology to reading research and determined that where the eyes go for fixations is of significance to normal reading and that during each fixation, only a word or two is being read. The length of time that fixation occurs is thought to depend upon the readiness of the individual to deal with the information that is displayed.

Mackworth (1968) investigated foveal and peripheral vision effects under conditions of (a) three-letter displays, (b) line displays consisting of 17 letters and (c) page displays consisting of 22 lines and 374 letters. In this work, Mackworth conceived of peripheral letters as potential "noise," and indeed did find that when foveal vision alone was used (1° subtended at a viewing distance of 28") nearly perfect recognition occurred. When peripheral vision became involved by introducing non-target letters (distractors) in the range of 3° to 10°, foveal and peripheral discrimination became necessary and recognition rates dropped to only about 10 percent.

Significantly, then, the reading disabled are adequately utilizing a narrow field of view, which consequently places a heavier cognitive load on the individual to grasp sentence construction and meaning. Stated differently, the simultaneous requirement for decoding at the word level

and abstraction at the sentence level produces an overload situation for the learning disabled individual.

In general, what the research suggests is that peripheral vision serves as an aid to decision making. If the letters or characters are non-contributory as they were in Mackworth's study, they will be interpreted as noise, forcing the individual to "shut them out." If they are contributory at a cueing level (word shapes and length of word) they "set up" foveal vision for efficient intake of the stimulus properties.

Perception effects on symbolic classification

Bruner (1960) has stated that "In learning to perceive, we are learning the relations that exist between the properties of objects and events that we encounter, learning appropriate categories and category systems, learning to predict and to check what goes with what."

Individuals learn by organizing the things they see into meaningful frameworks. To do this they identify those qualities of objects which allow them to be associated in some way.

For example, in spatial grouping, objects appearing close together are seen as related, as are objects having similar shape, size, etc. (Wertheimer, 1960). Thus, a string of dots becomes a dotted line; a string of closely spaced letters becomes a word. In temporal grouping, events and sounds occurring closely in time tend to be associated, as are ones occurring serially in a patterned sequence. Thus, pauses in oral reading tend to separate phrases and words thereby giving them emphasis, while in silent reading these pauses are prompted by punctuation that occurs in a particular sequential order.

In making associative judgments about whether a particular object belongs in a set, the individual relies on distinguishable features that define the object in space (Laberge, 1976). The letters a, n, i, and s can be distinguished on the basis of feature recognition. The words an, as, is, in, are distinguished on the basis of coding--which letter is in

front of which letter. At the level of automatic coding they are seen as stimulus patterns or global contours that constitute a code.

Referring again to Bruner's statement, we can easily illustrate why beginning readers have difficulty in the decision process (Does this go with that?) that is crucial to categorization and automaticity of word recognition. The letters G (italic), G (adjutant), g (gothic), and g (delegate) and the teacher's handwritten g, all stand for the same thing. This is not an easy categorization scheme to learn. Indeed, it is difficult to come up with a common set of characteristics that all Gs share. Instead, we build a loose set of coding guidelines for recognizing any in the "family" of G shapes. This looseness introduces a risk of over-generalization. For example, when presented with the following array and the question "What do you see?", almost everyone says "Gs."

GGGGG ggggg ggGCG

Clearly, that is not strictly true, it's just that in this context the set is toward Gs, and the C is close enough to be falsely grouped as a G. Insofar as the LD reader is concerned, this raises an important question. If the child does not recognize a word with the letter (or letters) G in it, the difficulty may rest in lack of familiarity with the typeface being presented and weakness in the learner's letter classification schema relative to that typeface.

Concentrating on letter recognition and word recognition per se is essential but not sufficient to the "grouping act" that is involved in reading. Bruner and Kenney (1966) use the term "modification" to describe the intersection of properties that occurs between words. For instance, the word hat has a meaning and the word green has a meaning, but the words green hat in combination take on a new "double classification" meaning. The LD student, then, must be prepared to recognize (1) letters as such, (2) standard sets of letters that form words with specific associative connotations, (3) possible multiple meanings for the same word, depending on adjacent words (the context), and (4) aggregations of words that form

sentences and present abstract ideas. Certainly, if the LD student does not distinguish letters and words clearly in the first place then their meaning is likely to be unattainable at any level of aggregation or generalization.

In exploring the mechanisms affecting an individual's procedure for search and recognition of characters, Sternberg (1968) experimented with degrading the features of characters and then studied the effects on recognition time. Sternberg applied his findings to existing theoretical analyses of how people differentiate between characters that are accepted or rejected. He concluded that a two-step operation takes place. The first step involves abstracting the physical properties of the stimulus representation, the second involves comparing this representation to prior memory representations, producing matches or mismatches. In effect, the individual searches for features in order to refine the image, then develops a "feature list" and through template matching or feature-list matching (in memory) confirms or rejects the character.

However, Gibson (1968) argued that learning was not dependent on matches to existing memory traces. He contended that it arose from natural perceptual stimulation consisting of "successions" and "adjacencies." So, by organizing spatial relations in an array and temporal relations in a sequence, information can be taken in progressively larger "chunks." This is the basis for rapid encoding and reading comprehension.

Olver and Hornsby (1966) studied the way in which <u>perceived</u> grouping becomes <u>conceptual</u> grouping as learners grow older and have greater experience with language. At age 6, 61% of groupings are pairs, at age 8 36% are pairs, at age 11 only 25% are pairs. For example, a house and barn are grouped "because they have red on them"--indicating a single attribute grouping. Edge matchings are often the basis for pairing by the young child ("This clock and this dish are round"), as are near objects ("The tree is next to the house"). Conversely, there is an increase in conceptually superordinate constructions ("They are all tools," "You can eat them," "They are ways you go places") from 34% at age 6 to 69% at age

8 and 85% at age 11. In essence, then, at age 6 equivalence for grouping is primarily based on visual similarity while at age 11 it becomes oriented around linguistic and symbolic structures.

Potter (1966) also studied how perception changes with age except that her work was related to perceiving pictorial images. In Potter's study images were shown first as badly out of focus and then the focus was improved step-by-step. She found that the very young (ages 4-5) made guesses about pictorial content based on their experience, 9-year olds fitted guesses together well but did not seek out logical implications implicit in shapes and colors, and high school and particularly college students formed "integrative" hypotheses followed by a checking of details. Teachers of the learning disabled are aware of their students' tendency to guess outright when ambiguous information is presented rather than to hypothesize and then check for details of a confirmatory nature, that is, they lack an "attack strategy" for perceiving, differentiating, and grouping complex stimulus materials.

Lerner (1981) points out that learners must move flexibly between being "whole perceivers" and "part perceivers" as their purpose dictates. For instance, the words house and horse require the individual to note an internal detail in order to distinguish them, not so with the word elephant, which is generally sight read without attention to the details of its spelling.

Word structure and usage

Much attention has been given to decoding; often this term has been used to describe the process of phonically sounding out words which are not at the automatic recognition level for that reader. As stated earlier, there is some basis to believe that the phonic method of learning to read works well for many girls (who tend to be able to segment well) but there is less basis to argue for its use with boys (who tend to think holistically). Since boys are more likely to be categorized as having reading disabilities, and sight reading of words is possibly the best strategy to use with them, it may be helpful to analyze the non-phonetic

structure of words to identify principles that could be incorporated in the design of computerized instruction.

The most critical letter to deciding what a word will be is the first one (Fisher, 1981). Given only that letter and either the knowledge of how long the word is, or its context from preceding words, or both, the word may be guessed fairly quickly and confirmed as its features are examined. The way in which one approaches confirmation of these features is important.

When the first letter is recognized, the position location of other letters in the word becomes critical. Assumptions about the probability of letter position contribute to rapid recognition. Confirmation of the word is apt to be quick if the second letter is correctly cued by the first. In this respect, the study of letter combinations or clusters can be helpful. The Glass Analysis approach to reading, for example, (Lerner 1981, p. 307) relies both on whole word recognition and the detection of letter clusters (pl and ay make play).

In a similar vein, when beginning and ending letters are perceived before the middle letters, recognition of the word is quicker than when middle letters are seen before the beginning and ending ones. We might think of sight reading, then, as a "filling in" of words to confirm initial expectations.

Apart from letter position and length, word recognition is more rapid when "the shape" of the word is "right." Strings of lower case letters serve as cues, as do ascenders and descenders at different locations in the word, for only certain words can "fit" within the perceived periphery. Thus the word "foot" has a very different peripheral shape from "moon" even though 50% of the letters are identical and the redundancy of the double o presents a strong perceptual cue in its own right.

In examining a basic word sight vocabulary of 220 words encountered across the preprimer to third grade reading level, it is immediately clear

that most of the words are short, and many of them are function words (there, may, very). This is understandable since these are the words that are basic to sentence building (Vaughan, 1971). The same is true (short, functional) for words that children use most frequently in writing, and therefore need to spell correctly. Several estimates indicate that about 2000 words constitute 95% of elementary children's writing (1000 words = 89%; 500 = 82%) so that it is obvious that a relatively small vocabulary receives a great deal of practice in school (Lerner, 1981). However, in rapid sight reading by proficient readers the short words and non-unique function words tend to be skipped over more frequently than content words (Fisher, 1981). This is also understandable since sentence meaning is principally dependent on content words.

An interesting dilemma results. Even though short words and often used function words are likely to be sight read easiest, partly because the typical eye-span range for serial recall is 6 letters or less and because of repeated exposure to function words, it is clear that high priority should be given to the expansion of the disabled reader's sight vocabulary of content words (Stanovich, 1982). There is a good chance that better comprehension will be obtained as well as more automaticity in word recognition through practice in reading a variety of short sentences in which content words are used repeatedly. Such a presentation of sight words and sentence practice could also help disabled readers to prepare for content words that have multiple meanings. "Note," for example, is likely to be quickly recognized, but has at least eight different meanings that are context (or curriculum) determined (Lerner, 1981).

The idea of keying on content words and then using short, functional words around them in short sentences is consistent with how children learn language in the first place. Bruner (1966) points out Brown and Fraser's contention that "child speech is a systematic reduction of adult speech largely accomplished by omitting function words that carry little information." He also cites Braine's extensive work with early sentential utterances of children. Their use of two word sets like "where dolly" or "where truck," "that dolly" or "that mommy" reveal an awareness that (a) there is a definite serial order to be followed and (b) either word can be

a "pivot" word which can be paired with other words to generate different meanings. This kind of paired rotation can easily be accomplished with computer-generated pivot words.

Attention

Samuels and Edwall (1981) have looked carefully at the role of attention in reading by the learning disabled. They conclude that five aspects of attention are critical:

1. arousal, a state of wakefulness measurable by physiological techniques,
2. alertness, a readiness for quick response,
3. vigilance, an ability to detect stimuli that occur infrequently over time or which are imbedded in regularly occurring events,
4. capacity, the amount of attention that can be allocated at any given time, and
5. selectivity, the ability to ignore what is not relevant in the environment.

Selective attention, then, can be thought of as an "economical form of perception." That is, enough features are distinguished to make identification but not necessarily all that are present. It is the "minimum principle" in Gestalt theory (Gibson, 1968). While it is clear that inattention to detail makes for sloppy recognition it is also true that overselective attention, where one aspect of detail is fixated, is also counterproductive. Autistic children will focus on one stimulus and ignore others, perhaps failing to recognize a father if he has his glasses off. What they are failing to do is scan the entire field and select the most salient components (Gersten, 1980).

Dykman, et al. (1983) have studied the physiological manifestations of learning disability with particular emphasis on attention. Distinctions were drawn between attention-in (as in mental problem-solving) and attention-out (as in responses to external tasks). A key conclusion drawn from the literature studied by Dykman and his colleagues is that "LD

children exhibit considerable inertia in switching from inner to outer involvement, evaluating the significance of stimuli, and becoming appropriately alert. Moreover, when one of these capacities is deficient the others also tend to be impaired...".

It is interesting that in an experimental comparison of three treatment groups of LD students, the treatment that reached significance in improving attending behavior was characterized in part by telling the students to "square their shoulders, lean forward, and look directly." (Argulewicz, 1982). This type of posture is not uncommon among students positioned in front of computer terminals.

Human factors

Hathaway (1984) has synthesized the findings from a number of studies of computer-based learning from the standpoint of ergonomics, the study of the interaction between human variables and machine variables. This is important because the efficiency with which learning takes place cannot be independent of such things as reflected glare on the computer screen, uncomfortable seating or positioning of the keyboard or monitor, or general room distractions. The principal variables analyzed by Hathaway in terms of their impact on attention, retention, and accuracy of response were:

1. Fatigue. Prolonged viewing of CRTs (cathode ray tubes) in sustained three hour blocks produced considerably more fatigue than did the printed page. Some neck discomfort may also occur in prolonged viewing. There is no evidence of fatigue being a serious consideration in shorter use periods such as takes place in most schools.

1. Density of displayed text. Faster, more accurate reading takes place when material is double spaced. In terms of numbers of characters per line, denser lines (80 characters) were read faster. In terms of page density, comparing printed text (40 rows per page) with less dense CRT text (18 rows per page), the print readers were 28-1/2% faster than the CRT readers. Note, however, that nine seconds were being lost each time a CRT "page" was turned and the screen refilled--a variable not encountered by the print readers.

3. Scrolling. No loss of comprehension occurs when text is scrolled 20% faster than the preferred scrolling rates of CRT users. Some 40% of the users, however, prefer static displays. Scrolling is conceived as moving a window (the CRT) over a stationary field. Windowing is conceived as moving the data beneath a stationary window. Users who employed the windowing notion in their viewing (selected by most users) performed search tasks significantly faster and with fewer key strokes.

4. Upper case vs. upper and lower case. Upper and lower case text was read faster and with more accuracy (about 2-1/2%). According to Hathaway, this translates to about three minutes of time per hour, or, in terms of testing, a possible 2-1/2 points less on a 100 point comprehension test.

5. Letter size. Viewers sitting 24 inches from the screen would read letters that are no larger than 3/16th of an inch for regular reading. Dot matrix resolution may be critical when the letter height is 3/32 or smaller.

6. Graphics. In presenting data, four formats were compared--narrative, structured tables, black and white schematics, and color schematics. Both graphic forms were preferred, with seven of eight subjects opting for color formats first and narrative formats last.

In addition to the variables in Hathaway's summary of ergonomic research, there are definite human-machine interactions that are machine specific. An example that applies to certain machines more than others is any prolonged wait that takes place while the operating system and disc drive function in response to learner input. Such delays, if they occur repeatedly, are apt to contribute to boredom, distractability and a loss of continuity in thought.

Cognitive Processes

Memory processes

Averbach and Sperling (1968) maintain that initial perceptions are received by a buffer storage or memory register capable of handling 70 or more bits of information. (A letter is counted as 4.3 bits of information.) However, they suggest that short term memory can only handle 20-25 bits, so that a relatively rich "instant intake" is possible,

but with relatively limited short-term recall. Several other factors operate to constrain the storage of information: (1) in the absence of any competing perceptions there is a decay of the buffered image ranging from 1/4 second to 2 seconds, (2) if perception of another icon occurs before processing into short term memory has been completed, the first information is erased or "masked" by the second, and (3) spatial resolution of the buffered visual information is "disturbed" when too many letters are put in.

In a discussion of capacity limitations in information processing, Shiffrin (1976) points out that masking does not simply refer to a serial replacement of perceived images, but also to lateral interference when a number of stimuli are presented simultaneously, as in a string of letters. Here, masking occurs when the spacing between letters no longer allows the features of individual letters to register clearly and separately, and fusion is made difficult. Shiffrin also points out that short-term memory is affected by the type of material presented and the rate of presentation. Specifically, short-term memory span increases sharply if the stimulus-input can be readily recoded into a category and is rhythmic or patterned, thus permitting it to be acquired in chunks.

A number of researchers (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Hasher & Zacks, 1979) have stressed the importance of efficiency in the encoding process. More particularly, they distinguish between "automatic" processes and those that are "effortful" or "controlled." Among the automatic categories of encoded information are spatial, temporal, and frequency-of-occurrence information, which are continuously and unconsciously being attended to without significant drain on the individual's capacity for encoding. Automatic encoding is learned and a function of what one has stored in long-term memory in terms of detection, search, and attention skills.

Controlled information acquisition, on the other hand, takes effort and includes such encoding techniques as rehearsal and mnemonic activities. It is clear, then, that even though rehearsal and mnemonic techniques facilitate chunking, the amount of information that can be

retained in memory, they do so at some cost in that they place new demands on the individual's limited processing capacity. Nevertheless, ongoing (unpublished) research by Margo Mastropieri and Thomas Scruggs at Utah State University and Joel Levin at the University of Wisconsin seems very promising. In their research handicapped students who are taught mnemonic "keyword" strategies exhibit striking gains (margins of 2 to 1) in recall of facts in science and social studies.

Problem solving and task strategies

Differences apparently exist in the way individuals apply cognitive abilities. Blackman and Goldstein (1982) have indicated that cognitive style (field dependence/independence; refection/impulsivity) is related to learning disability. Field independent learners, those who are not distracted but attend to relevant cues and discard the irrelevant, do better in school. Reflective individuals are more methodical, make fewer errors, and are superior in attentional behavior. Interestingly, Hynd and Obrzut (1981), having conducted a fairly extensive analysis of the relationships between learning disabilities and cerebral dominance, declare that "any method or remedial approach that decreases distractable tendencies seems most promising." They add that "... approaches attempting to facilitate the development of attentional abilities, rather than strengthen lateral preferences, should have the greatest probability of success."

Torgesen, (1980) in a variety of research studies, has established that an efficient task strategy is essential for good reading. In the sense used here, the term "task strategy" refers to a subject-directed choice of how to approach a reading task so that it is efficiently encoded into memory. In one study, for example, learning disabled readers did as well as normal readers in recall of digit sequences presented sequentially at one second intervals, but when the digits were presented in a horizontal array and studied for 10 seconds prior to recall they performed relatively poorly. They simply lacked a task approach strategy when presented with a character string that is similar to text.

Learning disabled children can be trained in such systematic strategies as the recoding or chunking of groups of items that go together, or in the use of mnemonic labels and rehearsal techniques (Miller, 1968). Torgesen (p. 24) states that "such training essentially eliminates performance differences between learning disabled and normal children." Although that claim may be extreme, Torgesen presents a strong case for the need to teach children how to use appropriate task strategies before they enter school and begin a cycle of failure and frustration.

Snow (1984) has examined the literature on human and artificial intelligence in an effort at understanding what contributes to problem solving that is complex, where prior knowledge seems to play a large part in performance. He describes the work of DeLeeuw at the Free University of Amsterdam, Holland, in which computers were used in an attempt to improve problem-solving abilities in public school students. Results seemed to indicate that students who were low in fear of failure performed better with heuristic (discovery oriented) instruction while students with debilitating anxiety did better with algorithmic (rule oriented) instruction.

Strategy training for reading comprehension has been demonstrated as a successful remediation technique. Brailsford, Snart, and Das (1984) showed significant gains for LD 9 to 12 year olds following 15 hours of special instruction in tasks such as:

- Magic Window - a picture identification task involving a window that revealed the picture, section by section. This task forced the child to synthesize parts into wholes in order to name the picture while it was only partially revealed.

- Matrix Numbers - a memorization task involving a matrix of five numbers positioned in a plus-shaped set of five squares. This task forced such strategies as verbal repetition and tactile use of fingers.

- Tracking - a schematic map tracking exercise in which houses and trees and geometrically regular trails were presented in a configuration not unlike a tree trunk with branches. This task forced children to perceive the spatial relationships among the map elements as they organized their travel task.

Computer Applications

What are the best ways to apply the computer in utilizing the various findings of research and the logic of established theory? This, of course, is a question that cannot be answered fully, both because little is really known at this time about possible "halo" effects of using computers and because the tremendous potential of the medium has yet to be explored in any systematic way. We are, however, aware of their appeal as motivators (through game-like programs that emphasize mastery) and as non-threatening tutors (in applications such as in word processing programs and to a lesser extent in drill-and-practice programs). The discussion of microcomputer instruction for the learning disabled by Schiffman, Tobin and Buchanan (1982), provides some helpful leads.

McDermott and Watkins (1983) deplore "the paucity of sound CAI research with the learning disabled." They point out that the attributes of CAI (computer assisted instruction) closely parallel teaching techniques recommended by experts on special education, namely:

1. frequent and immediate feedback
2. individualized pacing and programming
3. modularized and hierarchical curriculum
4. outcomes stated as performance objectives
5. a mastery learning paradigm
6. clarity of presentation
7. motivation
8. a multisensory learning format, and
9. personalized instruction

This similarity of special education goals and presumed qualities of CAI instruction are obviously not to be taken as automatic arguments for the use of CAI. Certainly poor programs do exist and one should not conclude that the indiscriminate use of microcomputer software will be advantageous in comparison to more "standard" classroom instruction. More will be said in another CREATE state-of-the-art paper about the availability of "good" software, how to identify it, and how to adapt or otherwise fit it into the curriculum.

Our review of the literature has uncovered some helpful suggestions for instructional design, not all of which directly discuss computers and software but which in one way or another lead to ideas that could be explored.

Potentially fruitful computer investigations

A number of possibilities arise for possible computer investigation. Some of the more promising ideas relative to reading skills are:

- Teach letter shapes by breaking them into curved and straight lines, emphasizing the angles, number of strokes, and directionality that are used (d b, p q); showing that neither the size of the letter nor the color changes the shape; teach letter pattern recognition to differentiate close but different words (hat, hate) to an automatic level; teach whole words as overall forms followed by the minimal confirmation of details that is necessary to establish word specificity (Chalfant & Scheffelin, 1969).

- With slower reading boys, emphasize whole word recognition rather than phonetic analysis (Chall reviewing Ansara et al, 1983).

- Develop a set of visual search tasks, one diagnostic and one remedial, such as "circling" a target letter in a field of letters (visual discrimination) or following a visual marker that moves progressively from the top to the bottom of the stimulus array (tracking) (McIntyre, 1981). A similar procedure could be used to locate specific words as is done when one is proofing.

- Teach the recognition of distinctive features in letter clusters (whether these occur at the beginning, the end, or centrally in words) by allowing students to "tack on" other letters to discover words that share these distinctive features (Miccanti, 1981). Words "earned" in this way could then be "saved in the bank."

- Build awareness of part-whole relationships (in both figural and verbal images) by using a moving "slot" through which various portions of the form can be displayed. The composite image will then be constructed by the viewer, combining "perception, apprehension, and imagination" skills (Badian, 1984). Variations could be tried where the slot "moves" or the concealed text "moves" with the size of the slot being variable.

- Build from single, stand-alone words to well spaced pairs of words, then three word sets, and eventually to horizontal lines. Others will assure that automaticity of word recognition precedes and transitions into the use of peripheral awareness to prescreen subsequent text, decreases the number of regressive eye fixations, and promotes contextual inference (Fisher, 1980).

- Bridge from discrimination learning to conceptual learning through the use of rules and examples (Gersten, 1980). Emphasize that the application of rules should not be taken as an absolute but rather represents an efficient first strategy Instead, for approaching the task (Example: key ideas are generally in the first sentence of a paragraph). Make allowance for variations in cognitive style through menu options accessible to the learner.

Use of the computer for vision training

One critical area that has been discussed at some length in this paper (and is unfortunately overlooked by many learning disability practitioners) has to do with the physiology of the eyes and their capacity to focus on and resolve print without introducing untoward amounts of strain and fatigue for the reader... thereby contributing to inattention and avoidance behaviors.

There is some evidence to suggest that as many as 50% of youngsters with "reading difficulty" actually have difficulty in viewing an image in a way that permits it to be seen clearly and with minimum effort. Given this prospect, high priority should be given to computer testing and therapeutic training in binocular vision processes. Among the neuromuscular processes of interest are fusion (including two dimensional and three dimensional fusion), phoria, and especially accommodation, tracking, and fixation. Additional priority should be given to visual processing speed and accuracy during saccadic eye movements so that reading speed is enhanced.

Fortunately, the Bernell Corporation (South Bend, Indiana, together with C.A.T.T., Inc.,) recently announced a computer system designed to test and train in visual processes of fusion, binocular fixation, tracking, and accommodation. While not inexpensive (approximately $3750) it utilizes a high tech, 16 bit machine with ghost-free video output and permits a great amount of control over the variables that affect learner response.

Vision testing, therapy and training in the vision processes at present are largely in the hands of opthalmic professionals (often with assigned home exercises conducted by parents). LD specialists who are not aware of this work and what it might do for their students should investigate it at the local level.

Use of the computer for perceptual enabling skills

Although the need for high quality computer software that addresses perceptual training (as distinguished from physiological vision therapy) seems clear for the learning disabled population, it has not been the focus of much software development and research to this point.

Bearing in mind that one needs to learn how to look before one can discriminate, and how to discriminate before one can read, we believe that for very young children any training should begin at the lowest level of abstraction (e.g., symbol differentiation) and increment toward complex visual fields (e.g., multiple lines of text). Throughout, effective attack strategies should be demonstrated.

One major computer-oriented study that has recently been conducted by Frederiksen (1983) at Bolt Beranek and Newman under sponsorship of the Office of Naval Research, aims at secondary school students with reading difficulties. While not beginning at the simplest perceptual training levels, the software developed does introduce what is termed "unit detection" and seeks to enhance perceptual encoding of orthographic information within words to develop automaticity. A causal link between a perceptual skill and decoding whas demonstrated.

Three microcomputer based training programs were developed:

"Speed" — a race driver game in which the learner tries to detect target multiletter units when they appear within stimulus words presented in increasingly rapid succession.

"Racer" — a horse and sailboat race game using computerized speech recognition and requiring the learner to correctly pronounce stimulus words.

"Ski-jump" -- a game in which early response leads to longer jumps while inaccuracy "leads to the hospital." The intent is to train in the use of context when selecting words that are appropriate to use in sentences.

Results of experimentation with the three games showed that "trainees were in all cases able to reach levels of performance in the trained skills that equalled or exceeded those of high ability readers. There was also strong evidence for transfer of acquired skills to other functionally related reading components."

The extent to which commercial software may exist that is suitable for the training of enabling skills of a perceptual nature is questionable. Clearly, a search of possible commercial software is in order as is a critical evaluation of the utility or adaptability of programs that are identified.

Use of the computer for cognitive processing skills

The use of computers to present intellectually challenging simulations or games that require higher level cognitive processing (such as reasoning) is not new. Some 15 years ago, the Sumerian Game was being played in North Westchester, N.Y. schools as part of an IBM project. It involved making economic judgments that would lead to "survival" of a simulated population with limited resources. Many of the design principles that were used in that project are as valid today as they were then (McKay, 1971).

Problem-solving games and puzzles are now sufficiently common in the software marketplace that they are often described in separate sections of publishers' catalogs. We suspect that most of these are designed for use by persons whose cognitive skills are fairly well developed and who need "a challenge." Learning disabled individuals, on the other hand, are looking for help in formulating a feasible study strategy first--one that works best for them. Only later are they likely to be ready for the application of that strategy to the specific subject-centered learning tasks they face.

Targets for research in Project CREATE

In deciding on the priorities for research that make the most effective use of Project CREATE's resources, we realize an obligation to work toward goals that are unlikely to be met by the natural evolution of the computer-based instructional technology but which have the potential for significantly improving the learning disabled child's effectiveness in the classroom.

Within this framework, it is doubtful that much attention will be given by the microcomputer industry to software development that addresses learner deficits in the area of perceptual enabling skills. To some extent this is also true with respect to the cognitive processing skills. In contrast, much work will be directed by commercial producers to the improvement of performance skills such as spelling, math, and reading per se. Therefore, CREATE will concentrate on the empirical development of software that builds fundamental skills in the perceptual and cognitive areas. In doing so, we will target fundamental skills that, when improved, should result in immediate increases in academic performance. Initially, we will concentrate on perceptual and cognitive skills that underlie the reading process.

Our work will begin with software that focuses on perceptual skills of cue differentiation, scanning, and pattern recognition. We will transition to chunking, contextual cueing, and memory-building cognitive processing skills. We will introduce letter recognition, word recognition, and sentence attack skills as final learning objectives in the various enabling and processing skills programs.

To the extent that time and the budget constraints of the project permit, we will design a range of software in which the difficulty can be set by the instructor for diagnostic purposes or set by the learner as a self-challenge. The software will be designed to monitor skill development against pre-set criteria as a basis for the learner's advancement to higher levels. Lastly, the software will be simple, easy

to use and intrinsically motivational and "gamelike." We hope that it will serve as a model which commercial producers choose to emulate.

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